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CITATION:

HISHIMOTO, YOICHIRO ...[et al]. The acoustical characteristics of dugong calls and the behavioral correlates observed in Toba aquarium. Proceedings of the 2nd International symposium on SEASTAR2000 and Asian Bio-logging Science (The 6th SEASTAR2000 Workshop) 2005: 25-28

ISSUE DATE:

2005

URL:

http://hdl.handle.net/2433/44078

The acoustical characteristics of dugong calls and the behavioral correlation observed in Toba aquarium

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ABSTRACT
Dugongs, *Dugong dugon*, are listed as Vulnerable to extinction in IUCN Red List. Previous reports suggested that there were some correlation between the behavior and the acoustical characteristics of dugongs. However, there was no continuous observation of an identified individual. We analyzed the acoustical characteristics of a captive dugong and the behavioral correlation in Toba aquarium, Japan. The purpose of this study was to predict its behavior based on the acoustical characteristics of dugong calls. In December in 2003 and 2004, we observed the male dugong (Junichi) in Toba aquarium. We used a digital video camera and a hydrophone to record the behavior and the vocalization of the dugong. Video-recording was taken in the daylight for 18 hours each (total 36 hours). The underwater sound recording was performed all through the survey for 31 hours each (total 62 hours). We recorded active movements (exposing its penis, rubbing its penis or body against objects, jumping out of the water, beating a water pillow with its flipper and running hard into wall). Through the observation, 616 calls were recorded. Call duration ranged 34-5039ms. These calls could be categorized by two types: short calls (chirp) that are under 300ms (380 samples) and long calls (trill) that are 300ms and above (236 samples). Call frequency ranged from 1.0 kHz to 8.6 kHz. All of the trains of calls with more than four calls were observed within 10 minutes from the active movements. The dugong made 38 very long calls (over 3000 ms). Almost all (94.7%) of the long calls were observed within 10 minutes from the active movements.

KEYWORDS: ***Dugong dugon, call duration, a train of calls, active movements***

INTRODUCTION
The dugong, *Dugong dugon*, (Fig. 1) is one of four extant species in the mammalian order Sirenia, all of which are aquatic herbivores (*e.g.* Marsh et al. 2002, Chilvers et al. 2004 among many others). The dugong is the only marine mammal that feeds on benthic sea grass and has a distinctive figure with the mouth opening ventrally below the broad flat muzzle. The feeding apparatus reflects their role as herbivores specializing on benthic feeding. Dugongs are easily found when they are feeding, by a stream of mud flowing in the feeding pathway of dugongs. The disturbed sediments and these clouds or streaks are assumed to be the result of the animals' rooting deep into the sea bottom. They are found in warm shallow waters of tropical to sub-tropical areas from Indo-West-Pacific between latitudes 26 ^{o} - 27^{o} North and South (Marsh et al. 2002). Over much of their range, dugongs are believed to be represented by separate, relict populations, many close to extinction or extinct (Marsh et al. 2002). They are listed as Vulnerable to extinction in IUCN red list.

Furthermore the Okinawa Island in Japan is the northern limit of the range of dugongs. In the Okinawa waters, they were designated as Critically Endangered by the Mammalogical Society of Japan in 1997. Mature individuals are presumed to be less than 50 animals (the Mammalogical Society of Japan). Dugong protection has become one of the important issues of Japan.

There is little behavioral knowledge about them. Acoustic signals produced by sirenians and the roles of these signals in behavior have been little studied. Dugong vocalizations were roughly classified into three types: Chirps, trills and barks (Anderson and Barclay, 1995). Chirps are frequency-modulated signals in the 3 to 18 kHz range lasting ca. 60 ms. Trills last as long as 2,200 ms, are frequency-modulated over a bandwidth of 740 Hz within the 3 – 18 kHz band, and have two to more harmonics. Barks are broadband signals of 500 to 2,200 Hz lasting 30- 120 ms with up to five harmonics. Frequency modulation of chirps suggested a ranging function. Trills were more appropriate for affiliative function and barks for aggressive behavior. To get some behavioral information from the acoustical information of dugongs, we made a continuous observation of an identified individual. The purpose of this study was firstly to investigate the acoustical characteristics of dugong calls (call duration, frequency, etc.), and secondly to investigate the acoustical characteristics and the behavioral correlation.

Ichikawa et al. (2004) suggested the method to identify the position of vocalizing dugongs, but it was difficult to observe an identified individual.

There had been no continuous observation of an individual dugong.

Fig. 1. A male dugong, Junichi, in Toba aquarium

MATERIALS AND METHODS

1. *Study site*

We conducted our experiments in Toba aquarium on two occasions. The dates of our experiments were 18th and 19th of December, 2003, and 9th and 10th of December, 2004. Each of our experiments was performed for 31 hours in a row, from 9 a.m. to 4 p.m. on the next day. The target animal was a male dugong, Junichi. The animal was 27 years old. Measured in 1999, his body size was 257 cm and his weight was 308 kg.

2. *Visual Observation*

We made a simultaneous and continuous observation by behavior recording, vocalization recording and visual observation (Fig. 2). The tank was connected with the tank of a female dugong (Serena) by the holding pool, but they couldn't swim through. The tank volume is about 200t (tank size: 10.0m × 5.9m × 3.4m). A hydrophone was set at the corner of the tank at 1 meter depth, and a digital video camera was set in the audience room. One observer listened to the noise of the tank and recorded the time of the calls. Another observer recorded the behavior of the male dugong in front of the tank. However, we couldn't make the visual observation at night because of the darkness.

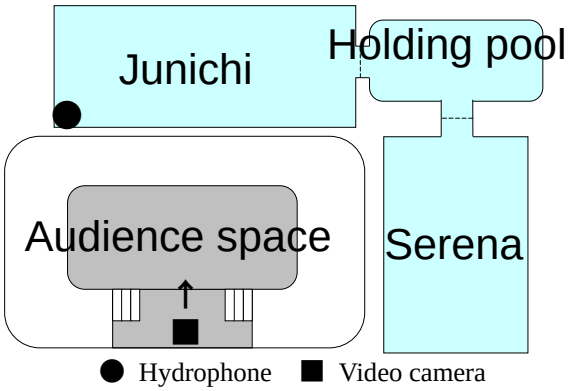

Fig. 2. The overview of the experiment

3. *Focused behavior*

We focused on the active movement of the male dugong. The active movement was defined as the following behavior. Our definition was supported by the definition of "sexual activity" by Toba aquarium, (1995).

- Exposing penis
- Rubbing his body or penis against objects
- Jumping out of the water
- Striking hard against objects
- Beating the water pillow with his flipper
- running hard into wall

RESULTS AND DISCUSSION

We recorded in total 616 calls in 2003 and 2004. We recorded 380 short duration calls (chirps: below 500 ms) and 236 long duration calls (trills: above 500 ms). But we could not record barks. Call duration ranged from 34 to 5039 ms. Call frequency ranged from 1.0 to 8.6 kHz.

1. *Active term*

From the examination, the correlation between calls and the active movement were implied. When the dugong vocalized a lot of calls, it seemed that he made some active movements (Fig. 3). We measured time intervals between dugong calls and the nearest active movements. If a dugong call is before the active movement, the time interval will be negative value. If it is after the active movement, the time interval will be positive value.

The frequency distribution of the time intervals is shown in Fig. 4. 72% of the time intervals were from -10 to +10 minutes. So, we defined the active term as 10 minutes before and after the active movement.

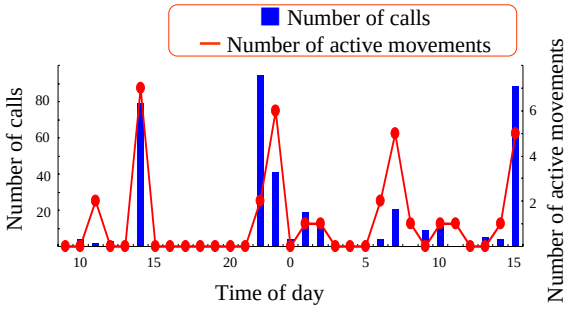

Fig. 3. Number of calls and the active movements per hour

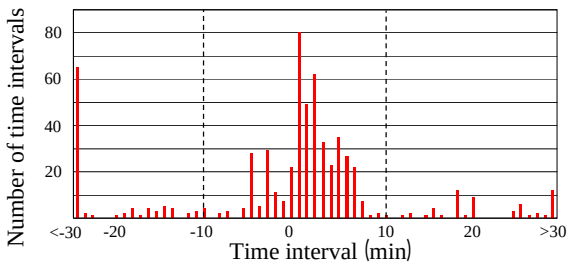

Fig. 4. The time interval between dugong calls and the active movements

2. *The correlation between the active term and acoustical characteristics (call intervals and call durations)*

2-1. *Call intervals*

We measured call intervals: the time intervals from the end of a call to the beginning of the next call. The most frequent call interval was the interval which was less than 1 second (about 23%) (Fig. 5). In this study, we defined "the calls in which the intervals were less than 1 second" as "a train of calls"

A train of calls was usually observed in the active term (Fig. 6). 72% of the trains of calls that included 2 calls were observed in the active term. 87% of the trains of calls that included 3 calls were observed in the active term. And 100% of the trains of calls that included over 4 calls were observed in the active term (14/14).

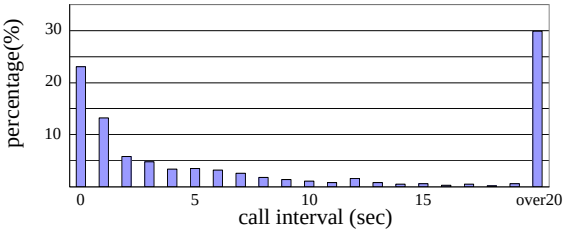

Fig. 5. Distribution of call intervals

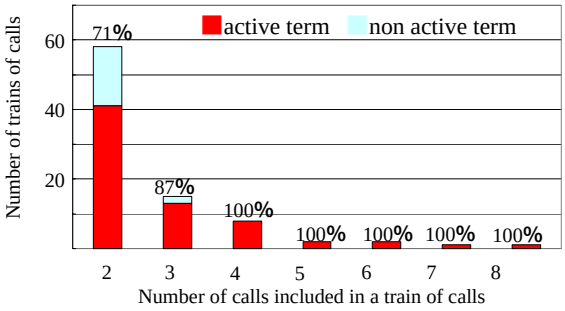

Fig. 6. Relationship between the active movement and a train of calls

2-2. *Call durations*

According to the distribution of calls, it seemed that long calls were usually vocalized in the active term (Fig. 7). Actually, long calls were usually observed in the active term (Fig. 8). In particular, the calls over 4 seconds were almost always vocalized in the active term (10/11). In previous reports, trills, long calls, had characteristics appropriate to affiliative functions and were associated with movements that appeared to be displays (Anderson and Barclay, 1995).

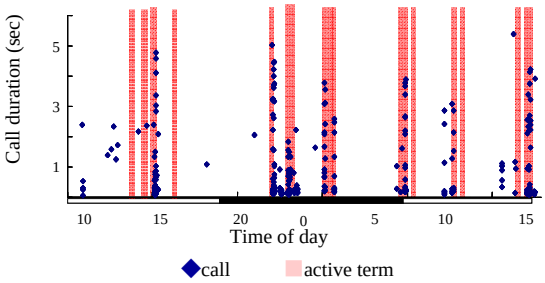

Fig. 7. Distribution of calls, call duration and the active term

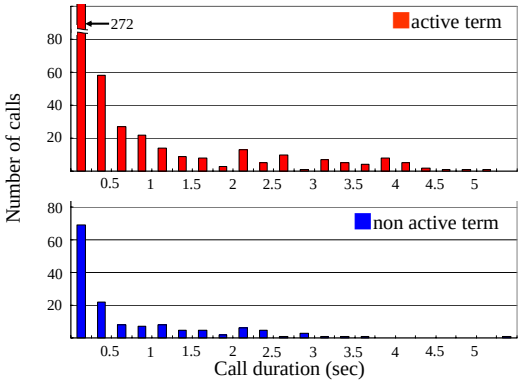

Fig. 8. Call duration and the active term

CONCLUSION

We recorded 616 calls of a captive dugong. Call duration ranged from 34 to 5039 ms. Call frequency ranged from 1.0 to 8.6 kHz. Trains of calls were usually observed in the active term. The calls over 4 seconds were almost always vocalized in the active term.

We concluded the acoustical characteristics of the captive dugong calls and correlations between a captive-dugong calls and its behavior. These results are important to understand ethology of dugongs and to elucidate the function of dugong calls.

ACKNOWLEDGEMENTS

This study was supported by Toba aquarium. We would like to thank Masami Furuta, the curator of Toba aquarium. We also thank the staff of Toba aquarium, Shiro Asano, Yoshito Wakai, Yukari Oka, Yukiaki Nakamura and the other staff.

We thank the staff and the students in the laboratories of Biosphere Informatics, Graduate School of Informatics, Kyoto University.

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